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Description

Laminated core testing arrangement

The invention relates to a laminated core testing arrangement for the purpose of testing laminated cores in a generator, the laminated core testing arrangement having a field winding, which lies in parallel with an axis of rotation of the generator and is connected to a high-voltage testing device producing alternating current, as well as an infrared image detection device which is designed to detect infrared radiation.

The invention also relates to a method for testing for faults in a stator of a generator, a high-voltage testing device producing alternating current being connected to a field winding which lies in parallel with an axis of rotation of the generator, and infrared beams being detected in the direction of the axis of rotation using an infrared image detection device.

Furthermore, the invention relates to a high-voltage testing device for a laminated core testing arrangement.

In generator design today, it is necessary to inspect generators intended for local and commercial energy generation for faults in the context of tests for early detection of damage. Faults may be damage in the rotor winding or damage in the stator. In the stator, damage may occur, inter alia, in the laminated cores or in the stator winding. The laminated cores are installed transversely with respect to an axis of rotation. In order to accommodate the stator winding, which generally comprises copper lines having a rectangular cross section, the laminated cores are provided with slots. The stator winding is introduced into the slots in an insulated manner. The stator winding is insulated with respect to the laminated cores.

The rotor of a generator has a rotor winding through which electrical current flows, the current level being up to 10,000 A in the case of modern generators. The electrical current is generally transmitted from an external power supply by means of sliprings and carbon brushes. In the case of limit-rating generators, the field current is produced by excitation machines having rotating rectifier wheels.

The electrical current induces a rotating magnetic field which in turn induces voltages in the stator winding located in the stator housing. An electrical current with considerably high current levels flows in the stator winding. The high current levels lead to the stator winding located in the slots being heated. The insulation between the stator winding and the laminated core may be damaged. If such damage occurs, the laminated core is heated in the local vicinity of the damaged insulation. Further damage could not be ruled out.

The insulation between the stator winding and the laminated cores is generally inspected for damage. A recent test method is to remove the rotor and to simulate an operating state which leads to heating of the laminated core. If the operating temperature is reached, an infrared recording of the stator winding and of the laminated cores is created by means of an infrared camera in a direction parallel to the axis of rotation. Faults or damage can be identified as so-called hot-spots and localized. The damage is eliminated prior to use.

Simulation of the operating state is nowadays performed by an arrangement which has a high-voltage generator and two or more phases of a field winding. The phases of the field winding are laid in parallel with the axis of rotation. The high-voltage generator is electrically connected to the field winding and produces an output voltage of up to 6 kV at a current level of approximately 700 to 800 A. The AC

voltage induces a magnetic flux or an alternating magnetic field in the laminated core which leads to desired heating owing to hysteresis losses, and this heating is comparable to the heating in the operating state.

Since the generators are generally tested in situ, it is virtually impossible to have a high-voltage generator available. To date only stationary high-voltage generators have been known which cannot be used in a power station.

Until now, the laminated cores have been tested in the factory. A further possibility for testing the stator winding and the laminated cores is the so-called EL-CID test which provides, however, limited information in the case of insulated laminated stator cores.

One object of the invention is to specify a further method and an apparatus for testing a generator which can be transported easily.

The object in relation to the laminated core testing arrangement is achieved by a laminated core testing arrangement for the purpose of testing laminated cores in a generator, the laminated core testing arrangement having a field winding, which lies in parallel with an axis of rotation of the generator and is connected to a high-voltage testing device producing alternating current, as well as an infrared image detection device which is designed to detect infrared radiation, the high-voltage testing device making available, at a frequency of more than 50 Hz, a power in single-phase form at an output voltage of at least 400 V which can be regulated.

The object in relation to the high-voltage testing device is achieved by a high-voltage testing device which produces a single-phase output signal which can be regulated having an output

voltage of at least 400 V and an output frequency of more than 50 Hz.

The object in relation to the method is achieved by a method for testing for faults in a stator of a generator, an AC testing device producing alternating current being connected to a field winding which lies in parallel with an axis of rotation of the generator, and infrared beams being detected in the direction of the axis of rotation using an infrared image detection device, the high-voltage testing device at a frequency of greater than 50 Hz making available a power in single-phase form at an output voltage of at least 400 V which can be regulated, and the detected infrared radiation being inspected for hot-spots which point towards faults in the generator.

The advantage can be considered, inter alia, to be the fact that an apparatus has been found with which it is possible to test generators for damage in situ.

The laminated core testing arrangement expediently has a controllable frequency converter for the purpose of converting a fundamental frequency into a higher frequency.

In order to make it possible to connect the laminated core testing arrangement to an AC power supply, the high-voltage testing device has an input side which can be connected to a three-phase power supply.

The three-phase power supply expediently has a three-phase 400 V AC voltage.

The high-voltage testing device expediently makes available an electrical power at a frequency of greater than 400 Hz.

Owing to an embodiment in which the field winding has at least two lines, it is possible to decrease the physical size of the laminated core testing arrangement further still. As a result, transportation of the laminated core testing arrangement is made easier.

Exemplary embodiments will be described with reference to the description and the figures, in which components provided with the same references have the same function and in which:

figure 1 shows the design of a laminated core testing arrangement, and

figure 2 shows an infrared recording.

Figure 1 illustrates the design of a laminated core testing arrangement. A generator (not completely illustrated) has a stator 1. The stator 1 is designed to be symmetrical with respect to an axis of rotation 2. The stator 1 has an outer housing 3. Laminated cores 4 are arranged perpendicularly and symmetrically with respect to the axis of rotation 2. For reasons of clarity, only two laminated cores 4 are illustrated in figure 1. The laminated cores 4 are arranged within the outer housing 3 from a stator start 5 to a stator end 6. The laminated cores 4 are fixed in the direction of the axis of rotation 2 in a manner which is not illustrated in more detail.

The laminated cores 4 have two or more slots 7 which are arranged symmetrically in the circumferential direction of the outer housing 3. A stator winding, which is formed from two or more stator winding bars 8, is arranged in the slots 7 of the laminated cores 4 in a manner which is not illustrated in any more detail. For reasons of clarity, only one stator winding bar 8 is illustrated in figure 1.

A rotor (not illustrated) is mounted such that it can rotate about the axis of rotation 2 in an inner opening 9 in the generator. The rotor has a rotor winding which comprises two or more groups of coils and through which a field current of up to 10,000 A flows. The rotor is induced to rotate about the axis of rotation 2 by means of a rotation device (not illustrated). The rotation device could comprise a steam turbine, a gas turbine or a combination of gas and steam turbines.

Owing to the field current and the rotating movement of the rotor, an electrical voltage is induced in the stator winding, and this electrical voltage can be made available as useful current via end stator winding bars (not illustrated).

The voltages and currents in the stator winding can assume values of up to 27,000 V and up to 35,000 A during operation. Such high currents result in a considerable amount of heat generation.

Insulation (not illustrated in any more detail) is provided between the slots 7 in the laminated cores 5 and the stator winding bars 8. The insulation prevents the electrical current from flowing in an uncontrolled manner and, as a result, a potential critical temperature increase.

In one test state which can be carried out in situ, a field winding 10 is arranged in the direction of the axis of rotation 2. In this embodiment, the field winding 10 has two field winding lines 10a, 10b. In an alternative embodiment, the field winding may have two or more field winding lines. The field winding lines 10a, 10b preferably lie on the axis of rotation 2. The field winding has two field winding ends 11, 12 which are coupled to a high-voltage testing device 13. The high-voltage testing device 13 makes available an alternating current at a frequency of greater than 50 Hz

in single-phase form at an output voltage of at least 400 V which can be regulated.

In one preferred embodiment, the high-voltage testing device 13 produces a single-phase output signal which can be regulated having an output voltage of at least 400 V and an output frequency of from more than 400 Hz up to 600 Hz in sinusoidal form. In a further preferred embodiment, the high-voltage testing device 13 produces an output voltage of more than 3.0 kV, in particular 2.0 kV.

The high-voltage testing device 13 has a controllable frequency converter for the purpose of converting a fundamental frequency into a higher frequency.

In one alternative embodiment, the high-voltage testing device has an input side which can be connected to an AC power supply. The AC power supply may in this case be a three-phase 400 V AC voltage.

Furthermore, the geometric dimensions and the weight of the high-voltage testing device 13 are such that transportation is possible in a simple manner.

It has surprisingly been found that, owing to the output voltage, the power and the frequency of the high-voltage testing device 13, a situation can be simulated which produces a state which comes very close to the state during normal operation of the generator.

Until now, laminated core tests have been carried out at frequencies of 50 Hz and output voltages of up to 6 kV. Until now there have been technical provisions for carrying out laminated core tests at higher frequencies and at lower output voltages.

The longitudinal voltages which are achieved in the novel laminated core testing arrangements are virtually identical to the values of the longitudinal voltages of the known laminated core testing arrangements.

Figure 2 shows a markedly simplified infrared recording which has been created by the infrared image detection device 14 during a test run. The infrared recording shows a section of the laminated cores 4 and the stator winding bar 8. In this case, the temperature of the laminated cores 4 and of the stator winding bar 8 is illustrated so as to correspond to an assignment scale 15. The allocation of a two-dimensional illustration and temperature can be seen in the assignment scale 15.

The hatched temperature 20 is lower than the dash-dotted temperature 21. The temperature 22 illustrated by an x is even higher than the dash-dotted temperature. For example, the temperature 20 is 20°C, the temperature 21 is 26°C and the temperature 22 is 30°C.

An infrared image detection device 14 is preferably arranged on the axis of rotation 2. The infrared image detection device 14 provides the possibility of detecting infrared radiation within the outer housing 3. The infrared recording shows a heat distribution across the laminated cores 4, the slots 7 and the stator winding bars 8.

For reasons of clarity, only three temperature values are illustrated in figure 2.

The infrared recording is evaluated during a test method. The temperature distribution should be as homogeneous and symmetrical with respect to the axis of rotation 2 as possible. The infrared recording shown in figure 2 shows that higher local temperatures prevail at different points.

These different points can be identified as damage 16, 17, 18, 19.

The different points having a higher local temperature are also known as hot-spots. Owing to the identification and localization of damage, it is possible for repair measures to be introduced. Subsequent damage during normal operation can be prevented effectively.